TITLE: ON LINE MEASUREMENT OF PRIMARY FINE PARTICULATE MATTER

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OBJECTIVE

The objective of this research is to investigate the feasibility of a two-color extinction technique to quantitatively measure fine particulate matter in a pulverized coal boiler. In this case the measurement system is theoretically capable of distinguishing particles 1 μm in size and smaller from larger coal, char and ash particles. The major contributor of these primary fine particles is thought to be soot. Soot particles are typically oxidized in pulverized coal boilers without significant amounts present in the effluent. However, NO_x reduction technologies that delay coal nitrogen oxidation inherently increase soot formation and decrease soot oxidation. This leads to the potential of soot stack emissions. In this work, a simple measurement of light extinction at two wavelengths is being investigated to determine if such a measurement can yield meaningful and accurate data of soot volume fraction and if the technique can be implemented on full-scale boilers for primary particulate control. Specific objectives include:

1. Identify the instruments to be used to optimize measurement accuracy while maintaining simplicity, affordability, and durability in application.

2. Build and test a prototype measurement system on a pulverized coal reactor.

3. Demonstrate the measurement technique is capable of measuring soot in-situ and that it is quantitatively the most accurate method available. To do this a series of comparisons between the two-color method and other soot measurements will be made. In addition to calculations of errors involved in all available techniques.

4. Determine the feasibility of measuring soot in a full scale boiler using the two color extinction method.

ACCOMPLISHMENTS TO DATE

A two-color extinction system has been designed, constructed and tested. The design led to the selection of helium neon lasers for the light sources at 543 and 633 nm. It was determined that a combination of 488 and 633 using an air cooled argon ion laser and a helium neon laser respectively would produce the highest signal to noise ratio; however, two helium neon lasers were used because of the higher cost of the air cooled argon ion laser. This prototype system has been used to evaluate the measurement limit of the technique which appears to be near 1×10^{-8} soot volume fraction. The two color measurements have been compared with the presence of luminous soot in the flame and soot in the effluent gasses. In both cases soot appears visually under the same conditions it is found using two-color extinction. Soot begins to form near the inlet when the overall stoichiometric ratio is greater than one but burns out by the end of the reactor unless the equivalence ratio exceeds 1.2. Scanning electron microscope (SEM) pictures of the effluent particles have also been taken to determine if soot can be seen in more abundance at the same conditions they are found in the extinction measurements. Soot has also been measured at two equivalence ratios and three swirl conditions throughout the length of the reactor.

SIGNIFICANCE TO FOSSILE ENERGY PROGRAMS

An important new tool has been developed for the measurement of soot within coal flames. This technique can identify soot separate from the coal, char, and ash. It will allow for monitoring of soot stack emissions on a real time basis and can be used within a boiler to monitor the location of the luminous combustion zone. Because of the rapid system response, this measurement could be used in conjunction with a control system to monitor and alter combustion characteristics in a boiler in real time. This will make some advanced NO reduction strategies more feasible and environmentally acceptable because control systems will have real time measurements to provide input. The soot measurements themselves are also valuable to help determine rates of radiative heat transfer which is needed to calculate combustion temperatures.

PLANS FOR FINAL MONTHS

The measured soot concentration values will be compared to the best available method for measuring soot. This currently consists of sampling the soot and attempting to separate it from the char, coal and ash using a centrifuge and settling. The soot will then be weighed and the concentration determined. This appears to be the only other technique known for quantitatively measuring soot in coal flames. Additional measurements of soot will be made under various operating conditions in the coal flame. An analysis will be done on the possibility of applying the technique to large scale boilers. A proposal will be written to attempt a full-scale implementation.

ARTICLES, PRESENTATIONS AND STUDENT SUPPORT

Presentations

- Tree, D. R., Clark, A., Jackson, R. E. and Peart, J., "In-Situ Species, Temperature, Soot and Velocity Measurements of Pulverized Coal Flame," Advanced Combustion Engineering Research Center Conference, Provo, UT, March 1999.

STUDENTS SUPPORTED

Jacob Peart, Graduate Student (MS) in Mechanical Engineering, August 1999.